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HUMAN RESOURCE INNOVATION
MARINE INDUSTRY STANDARDS
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EDUCATION AND TRAINING

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U.S. DEPARTMENT OF THE NAVY
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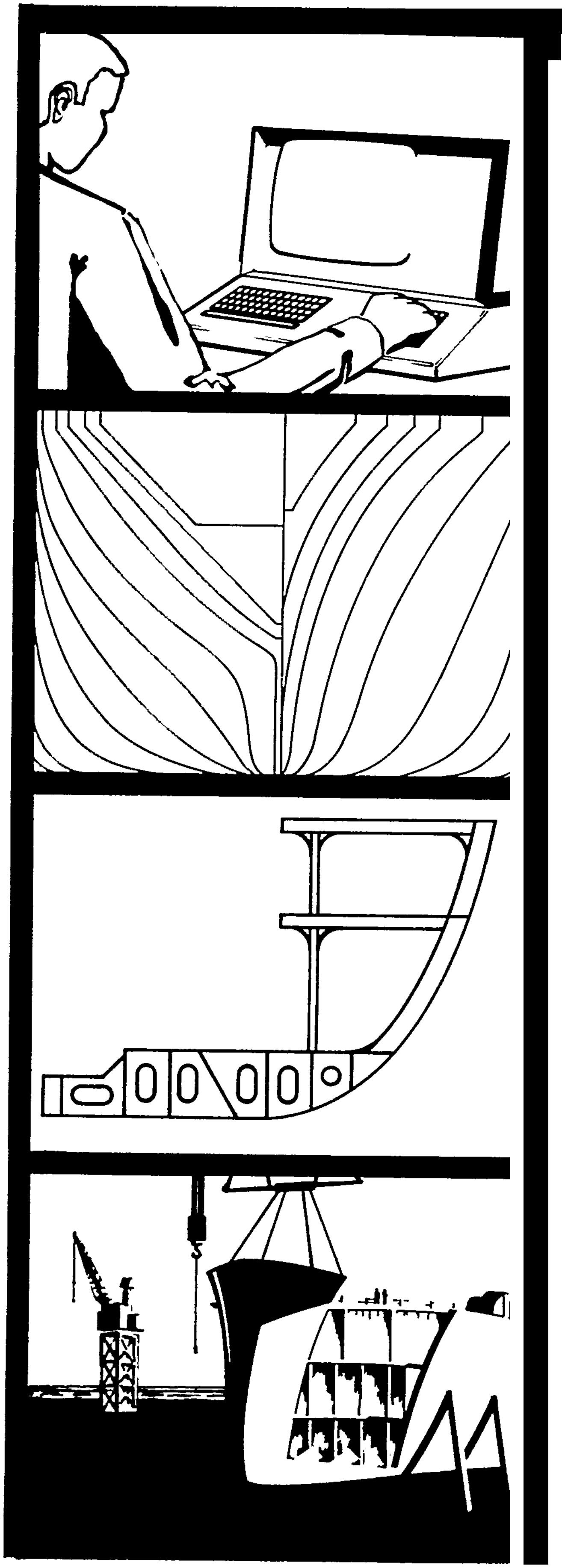

**R**ESEARCH AND **E**NGINEERING FOR **A**UTOMATION AND **P**RODUCTIVITY IN **S**HIPBUILDING

# Proceedings of the REAPS Technical Symposium

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# DISCLAIMER

# COMPUTERS IN SHIP DESIGN AND PRODUCTION: NECESSARY STEPS TO THE PAYOFF

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## INTRODUCTION

During the last decade, numerically controlled (N/C) flame cutting systems have established themselves firmly as an integral part of the shipbuilding industry, but the computer software systems which have been developed to generate the N/C instructions prove to be a continually growing and expanding component of the' process. A number of such systems are commercially available, all vigorously developing new capabi.liti.es which are marketed as successive versions of the systems.

This paper cites directions of new development in a. number of the-leading systems and generalizes to identify several visible trends in the development of shipbuilding software. systems. These trends are explained in terms of the technical and economic mechanisms driving them. We should expect these trends to culminate in a new payoff of benefits distinct from the advantages which we currently realize from N/C processes.

The pathway from the present situation to the realization of this payoff contains pitfalls, however. This paper will attempt to illuminate one such hazard which has been 'underpublicized, which we can do something about, and which we must act on, now or the opportunity will be lost.

## TRENDS

As in most businesses today, electronic data processi.ng (EDP) is well established in the administrative operation of shipyards; in this paper we are not primarily concerned with that usage of computing. In technical functions, programs have long been used for weight calculations, structural analysis, and a modest number of other isolated scientific tasks, but this usage has had a correspondingly modest impact on the ship design and construction process in our shipyards. The first major impact of the computer on the design/production shipyard operation has been to support N/C flame cutting.

N/C tapes were initially produced very laboriously using rudimentary parts programming languages. The effort of loading digital data to produce N/C tapes has subsequently been reduced with the development of more sophisticated parts programming languages, with the usage of "macros" and "norms," and by the technique of storing the hull molded surface one time and merely referencing it as necessary for position information respecting particular parts. Eventually algorithms were added to fair the hull surface and to assist in loading data respecting longitudinal stiffening into the data file, also to be referenced when defining parts. The original motivations for this aggregate parts programming capability were the reduced cost and increased dimensional accuracy of automated manufacture, and the successive development of the capability has been driven by the need to reduce costs of the N/C input task. The ongoing extension of this trend in today's shipbuilding N/C systems is toward inclusion of capabilities explicitly for the design/engineering phase of the shipbuilding process. The continuing and apparently natural growth of computer impact is from the Production Department back up through the process into Design and Engineering.

Figure 1 cites some of the newer areas being emphasized in several of the principal shipbuilding computer systems. These development efforts are more fully described in references through 7. Although there is an apparent diversity of development emphasis, it will help us cope with this expanding field if we recognize and accept that the most significant trend in shipbuilding computer systems is their continual incorporation of additional functions.

Figure 2 represents this dominant trend as the phenomenon of increasing higher integration of these systems in five distinct dimensions.

We have already noted the extension of systems "up the process" in the direction of design/engineering, and more will be discussed on this later.

- We can see also the inclusion in the automated process of more parts of the ship structure, such as transverse structure and small structural parts (chocks, tripping brackets, sole plates, etc.), and one may reasonably extrapolate the trend to eventually encompass foundations.

- Some systems are beginning to integrate across design disciplines to facilitate coordination of piping, structure, and arrangements.

- There is a growing awareness of the need to integrate the technical data with data files for management and administrative functions (estimating, scheduling, progress reporting, procurement, etc.). In a landmark state-of-the-art survey of computer-aided design (CAD), Hatvany *et al* state:

  > The satisfactory solution to creating an efficient output interface for CAD in each case requires basic consideration of the integration of the entire design, manufacturing, and administrative process. Without this, only partial ad hoc solutions can be found. (Reference 8)

WORLIMIDE SHIPBUILDING COMPUTER SYSTEMS ARE EMPHASIZING NEW APPLICATIONS

- AUTOKON: OUTFITTING, STRUCTURAL DETAILING, STRUCTURAL ANALYSIS OPTIMIZATION, PIPING ARRANGEMENT, GENERAL-PURPOSE DRAFTING
- BRITISH SHIP RESEARCH ASSOCIATION, SHIP STRUCTURAL DESIGN SYSTEM (SSDS): INTEGRATION OF DESIGN AND PRODUCTION, CENTRAL DATA BASE, STANDARD STRUCTURAL DETAILS
- ITALCANTIERI, SCAFO SYSTEM & OTHERS: HIGHLY INTEGRATED SYSTEM OF STRUCTURAL & ARRANGEMENTS DESIGN PROGRAMS WITH MANUFACTURING & PROCUREMENT-ORIENTED SOFTWARE
- HITACHI, FNC SMALL SYSTEM: INCORPORATES SMALL STRUCTURAL PARTS INTO AUTOMATED PRODUCTION PROCESS
- KOCKUMS: INCORPORATING SMALL STRUCTURAL PARTS, EMPHASIZING PLANNING AND ADMINISTRATIVE FUNCTIONS
- SPADES: PRODUCTION PLANNING & SCHEDULING, STEEL MATERIAL CONTROL, STRUCTURAL DRAFTING, MORE POWERFUL STRUCTURAL DATA LOADING

FIGURE 1

THE MOST SIGNIFICANT TREND IN SHIPBUILDING COMPUTER SYSTEMS IS THEIR CONTINUAL INCORPORATION OF ADDITIONAL FUNCTIONS,

THIS TREND MAY BE CHARACTERIZED AS INCREASING HIGHER INTEGRATION IN 5 DIMENSIONS:

THROUGHT THE-SHIP DESIGN/PRODUCTION PROCESS

INCORPORATING MORE 0F SHIP STRUCTURE

ACROSS 'DESIGN DISCIPLINES

WITH ADMINISTRATIVE FUNCTIONS

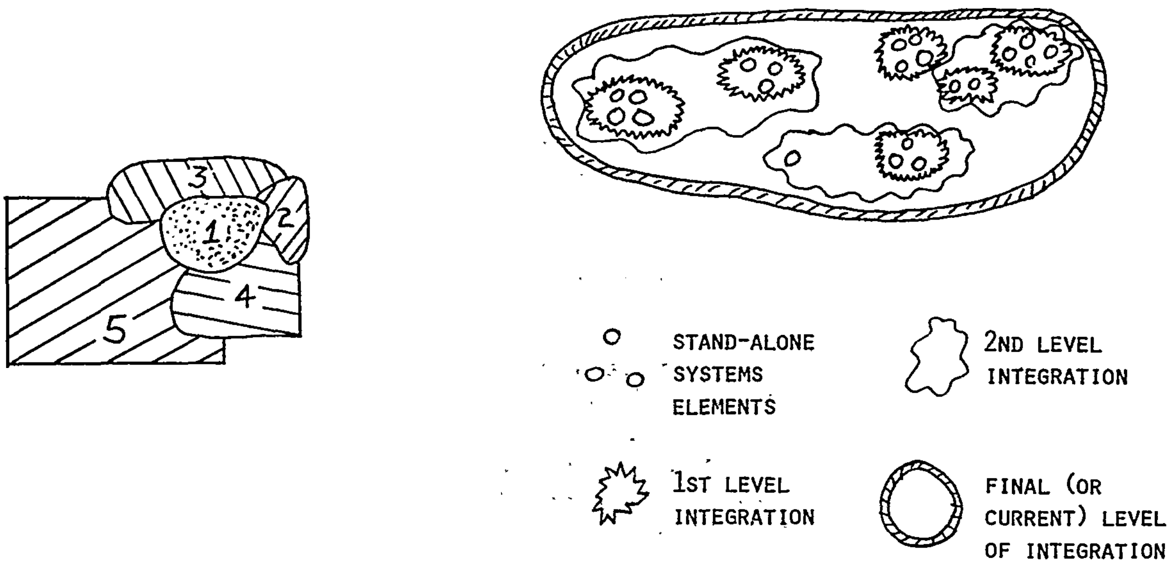
WITH OTHER ORGANIZATIONS IN INDUSTRY

FIGURE 2

- Finally, the high cost of developing and maintaining these increasingly complex systems is demanding that users pool their resources <u>with other industry organizations</u>, thereby requiring and establishing a level of integration across corporate lines.

In the growth of shipbuilding computer systems, we can observe two forms of accumulative integration, as depicted in Figure 3. Tangential integration, wherein one original "core" program' is successively expanded to encompass additional adjacent tasks, is perhaps best representative of our overall trend. Often, however, two programs begun independently grow together as one or both incorporate functions which link them. We can refer to this clustering phenomenon as hierarchical integration, because it often occurs recursively within an organization's functions.

TWO FORMS OF INTEGRATION GROWTH




TANGENTIAL INTEGRATION

HIERARCHICAL INTEGRATION

**FIGURE 3**

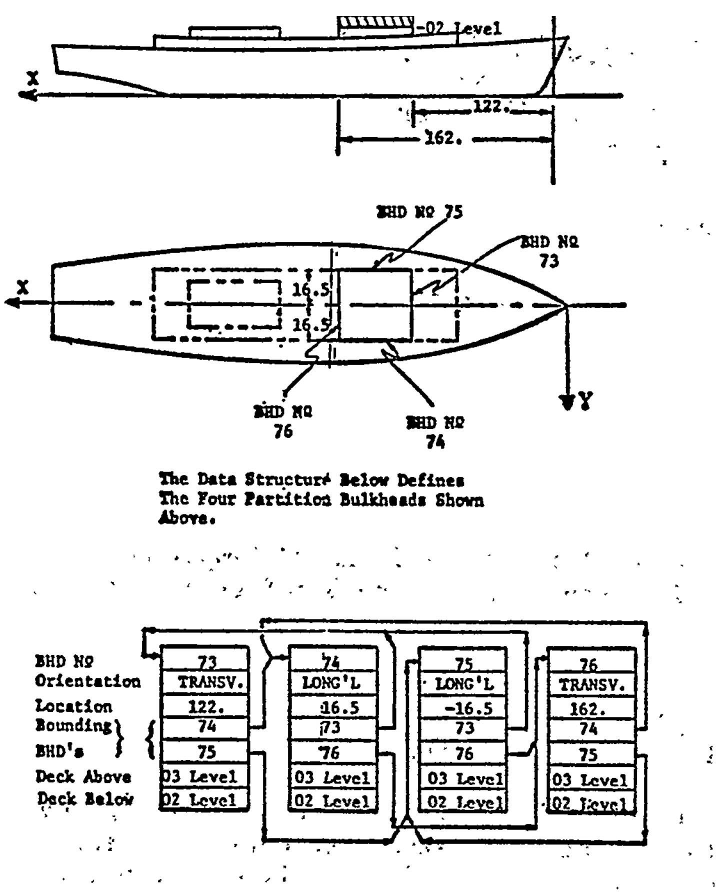
As an example of hierarchical integration, in the Navy's Computer-Aided Design and Construction (CASDAC) system (reference 9) we have seen manual dsiign tasks replaced or facilitated by stand-alone computer programs (e.g., the UPLOT programm for computer-assisted drafting). Stand-alone programs have often been consolidated into suites of complementary programs (e.g., combining UPLOT with an interactive graphics arrangement program, COGAP, to provide improved arrangements drawings). Program suites have been superseded by larger "subsystems" "which address entire design disciplines (e.g., the new Arrangements Subsystem provides a full complement of ship arrang ernents functions, including those of COGAP/UPLOT). These subsystems must be interfaced to comprise a total coordinated computer-aided contract design system "(CASDAC Level III), and this system will eventually be required to interface with shipyard design and with the vendor community.

Whether a particular step toward higher integration is predominantly tangential or predominantly hierarchical, the most common motivation is the situation where a new and common functional boundary exists, across which information passes and which is inefficient to support manually. Before integration, this data flow requires manual (or perhaps computer-assisted) copying, reformatting, calculations and/or re-digitizing (e.g., card punching) which incur inordinate expense and which could be alleviated by making the two functions or programs or systems "talk to each other." As an illustration, consider how interactive graphics parts nesting bypasses the plotting and cutting out of small-scale parts templates, the manual nesting of the templates, the recapturing of digital part position data via digitizer or manual card punching, and the verification of nested formats in batch mode plotting. Hence, another step up the integration ladder.

There are several other visible trends in shipbuilding computer systems which are accompanying the higher integration. There has been a startling popularity in the last two years of interactive graphics, whereas the traditional mode of operation has been batch mode with punched card input. Interactive graphics technology has come of age, and is finding effective roles in parts definition, nesting, and arrangements.

Another definite trend is the increasing cost of the more complex, more highly integrated systems. One shipyard indicated that the operation, maintenance, and modification of its N/C system required the continual effort of between three and six programmers. The cost estimated to convert to a second computer and to document another large, contemporary shipbuilding system is well into seven figures. Our computer software is becoming a very expensive commodity of the trade.

Finally, a trend of vital importance to this discussion is that system developers are recognizing the design data base as the central element of the design system. The British Ship Research Association (BSRA) describes their Base System as the "kernel" of their new Ship Structural Design System (SSDS). A particular characteristic of progressive design data bases is their use of topological data structure. This technique is currently being used in defining the spatial retionships among surfaces, lines of surface intersection, and volumes bounded by the Surfaces. With this method the absolute coordinates of intersection lines are not explicitly recorded; instead, the geometric shapes of the intersecting surfaces are recorded and are retrieyed and operated upon to compute the lines of intersection when these are required. Figure 4 illustrates such topological data in a Navy arrangements program (reference 10) and Figure 5 illustrates topologically recorded intersections between longitudinal surfaces (decks, bulkheads, tank tops, etc.) and the hull in Italcantieri’s SCAFO system.




SAMPLE TOPOLOGICAL DATA STRUCTURE IN

THE INTEGRATED SHIP DESIGN SYSTEM

**FIGURE** 4

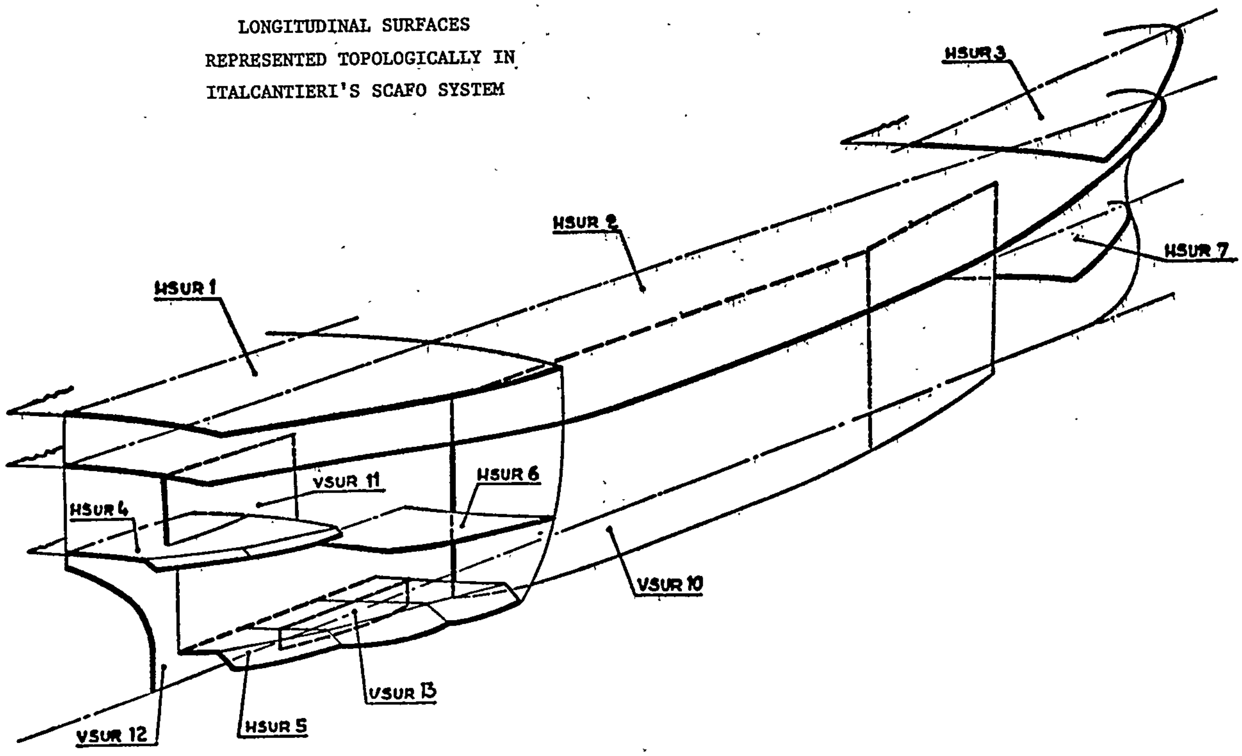



FIGURE 5

In his paper (reference 1) for the 1977 REAPS Symposium, Jan Mack identifies and discusses these three benefits of topological data structure:

- Less data input
- Ease of updating changes
- Flexibility in work sequence

It should be noted that a corollary to "ease of updating changes" is the fact that in a topological data structure data redundancy is minimized and therefore the data base is inherently more consistent. Italcantieri claims that SCAFO's topological data structure affords a very desirable flexibility in work sequence, due to the fact that changes to the molded surface locations of both shell and internal surfaces do not require radical recomputation of many structural details.

It should be understood that the benefits of a topological data structure described above are germane while the data are in a state of change. Once a design has stabilized, it is often more efficient to freeze the design and record the data in absolute form for direct use thereafter. An, effective data management system should allow this transition from topological to absolute data representation during each design.

## THE PAYOFF

### Why Benefits Are Expected

Before contemplating the specific anticipated benefits of more highly integrated systems, it will be helpful to understand the mechanisms at work which yield these benefits. I will identify and briefly describe three such mechanisms.

MECHANISM #1: ONCE DESIGN INFORMATION IS "CAPTURED" AS DIGITAL DATA, IT CAN-DRIVE MANY APPLICATIONS.

As a familiar example, consider the spin-off benefits which became available at very little additional effort once N/C systems had recorded shell plates and hull longitudinal. Roll templates and 3-D templates for developed plates were easily produced. Inverse curve data for bending frames and longitudinals was made available, and tables of pin heights for shell assemblies were generated. These capabilities eliminate much manual transcribing of data, checking, and resolving of errors.

Similarly, it is a trivial matter to compute percentage of scrap and times required to punch and burn each plate, given information required for an N/C tape itself.

MECHANISM #2: SHIFTING THE "DIGITAL FRONTIER" FROM THE PARTS PROGRAMMING STEP TO A POINT EARLIER IN THE DESIGN PROCESS GREATLY REDUCES THE QUANTITY OF DATA TO BE LOADED.

We know that the quantity of design information grows exponentially during the design process, probably as the exponential "S" curve illustrated in Figure 6. Presently, detail structural design is performed manually, and at the conclusion of detail design the structural

MECHANISM #2: SHIFTING "DIGITAL FRONTIER" FROM PARTS PROGRAMMING TO EARLIER IN DESIGN PROCESS GREATLY REDUCES QUANTITY OF DATA TO BE MANUALLY LOADED.

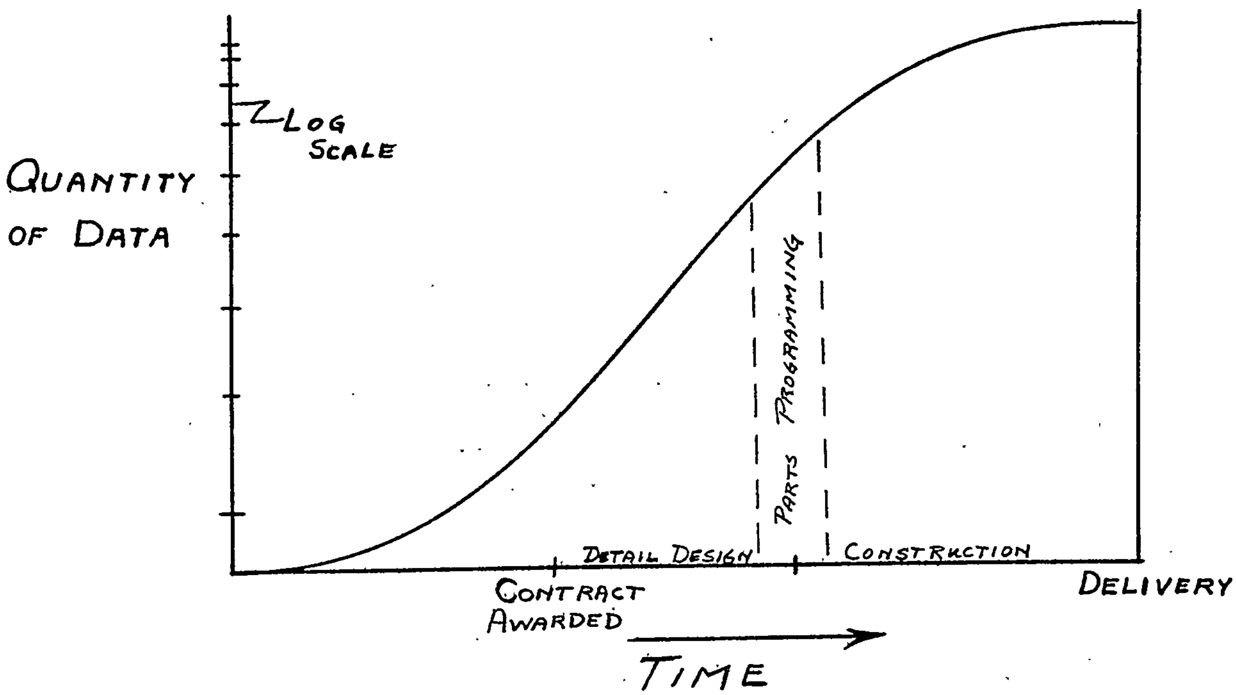



FIGURE 6

geometry is transformed into digital data during parts programming, a very time-consuming task. As the increasing usage of CAD in detail design shifts this "digital frontier" up earlier in the design process, less input will have to be manually loaded and the bulk of the input data required later in the process will be generated by the new design programs.

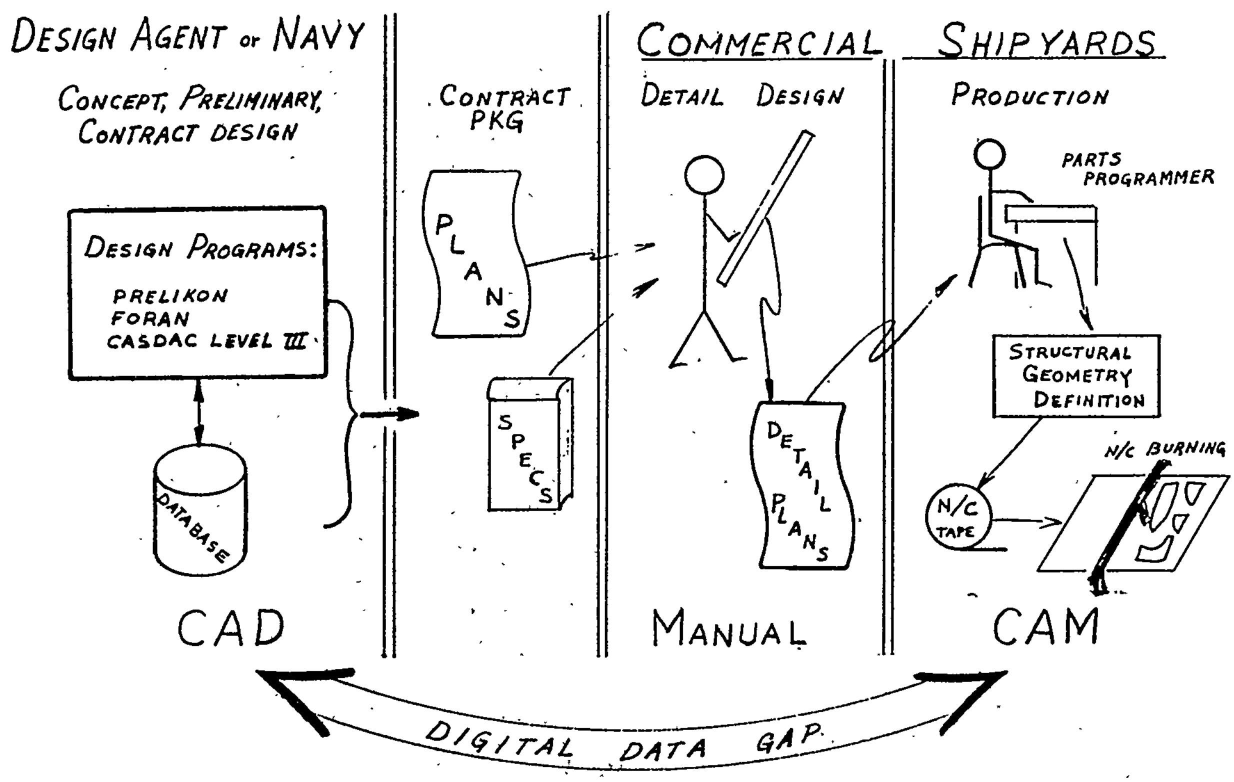
MECHANISM #3: INTEGRATED SYSTEMS CAPITALIZE ON CONTINUITY OF FLOW OF CONSISTENT DATA THROUGHOUT THE PROCESS.

We have already been introduced to this concept as the most frequent motivation for integration. Since the manual handling of digital data is generally espensive, error-prone, and unnecessary it is useful in system design to be conscious of continuity of data flow in the system, recognizing that flow continuity usually requires that the form of data be consistent as well as the information content.

Bearing in mind these three mechanisms and recognizing that various computer-aided design software exists now or is under rapid development in the early design stages (PRELIKON, Sener's FORAN, Navy's CASDAC Level 111), detail design stands out *as* representing the major gap in the flow of digital data (see Figure 7). As the CAD software in early design matures to produce a complete, reliable contract design data base, and as current development efforts move the digital frontier backward from parts programming across detail design to meet that data base, we may expect to see a marked improvement in the effectiveness of our system as that gap is bridged. Such integration of the design and manufacturing functions will realize much greater benefits than would the independent sub-optimizations of each.

## Benefits in Structural Design

Once the structural geometry definition of the ship. is being stored and used in digital form, the structural engineer will have a versatile and convenient means for obtaining graphic representations of the current structural configuration. He may request plans for whole decks or bulkheads, he may ask for sketches of arbitrary sections through existing structure, or he may ask for particular local details. He may identify which views he would like shown and how he wants them formatted on a drawing. He may designate which structural surfaces or elements he wants shown, the level of detail he wishes depicted (scantling drawing, structural drawing, structural details), and he may selectively call for inclusion or suppression of notes, piece numbers, weld symbols, labels, dimensions, etc. In short, the engineer no longer must pick the information he needs off standard drawings whose format and content were




CAD MUST INTEGRATE ACROSS ENTIRE DESIGN/PRODUCTION PROCESS.

FIGURE 7

decided by others; he may now very quickly compose sketches and drawings to suit his individual and immediate needs.

The structural graphic representations just described would be available via several mediums. Interactive graphics terminals would serve as the primary man/machine interface. The engineer would compose displays exercising the capabilities and options described above. He would get electrostatic copies of the displays virtually instantaneously, and he would use these copies directly for reference in much of his own design work. High quality drawings, when required, would be produced from the graphics display via drafting machine.

In one of our more progressive shipyards which uses one of the popular N/C systems, engineers have begun to request drawings of molded contours from the N/C data base. These drawings they then arrange in appropriate locations under a fresh. sheet of mylar and the contours are manually traced as the outlines of their new bulkhead drawings. Certainly this procedure can be adjusted to more conveniently serve the engineer's need, but the significant point is that the data base and its graphic output capability have been recognized as a precise and reliable means of obtaining molded surface information. It certainly beats manual interpolation from a book of offsets, or scaling down a 1/10 body plan to an appropriate scale! The proposed capability for producing displays and drawings of the structural configuration is merely the extension of this basic capability to its full potential.

The last few paragraphs have described both passive and interactive graphics as useful output tools. Interactive graphics will also be used to provide the designer with a convenient and powerful tool for defining-structural geometry to the data base, eliminating most of the card input/batch mode data entry we know today. Programs on interactive cathode ray tube (CRT) scopes will display existing structure as described above, then will assist in structural design by quickly arranging grids of stiffeners at designated spacings, running seams and stiffeners parallel to existing structure, repeating groupings of minor structure, etc. Immediate visual confirmation will reduce input errors common in batch mode operation. Where appropriate, computer-produced sketches of existing structure can be manually marked up to show modification and/or new structure, and these modifications can be input via digitizer device working from the marked-up sketch.

Topological data methods would be used not only to represent molded surface intersections, but also to record stiffening located on a surface and to identify the extents of structural numbers. For instance, toe traces of bulkhead stiffeners might be defined to align with a deck longitudinal above and a bottom longitudinal below. If the location or scantling of the deck longitudinal were to change, it would require no modification to the topology of the bulkhead stiffener. Since detailed piece lengths and end cut details would not be stored explicitly, they would require no updates. The structural design tasks would realize the benefits of topological data structure discussed earlier in this paper.

Structural piece lists could be, generated with practically no effort and in virtually zero calendar time. Manual "material take-offs" from drawings would disappear and the piece lists would be consistent with both drawings and data base. Furthermore, variations of piece lists could be tailored to particular uses at very little cost, to provide various formats, meaningful subsets of lists, or different ordering of list items.

Availability-of digital structural data would feed a variety of analysis programs from simple section, rnodulus calculations, to indeterminate frame analyses, to providing data for a closer interface with finite element methods. Structural weights and centers of gravity could be computed automatically, precisely, and-as often as necessary.

The existence of a structural data base would assist in foundation design by providing s-ketches of local primary structure. The digital description of equipment location, coupled with graphics templates of mounts, base plates, bolt hole configuration, etc., would enable superposition of mounting details on the local structure sketches. The convenience of this capability alone would considerably facilitate the manual foundation design task. A more ambitious interactive foundation design capability would, compute support forces due to various loads, would allow the designer to interactively describe the foundation structure, would compute forces and stresses in the foundation structure, and would allow the designer to indicate recommended modifications to the local principal structure, if ne,ceyisary.

Finally, benefits will be realized from linking the shipyards' detail design CAD systems with contract design data bases produced by design agents or by the Navy using CAD in the early design stages. This availbility of scantling plans in digital form will further reduce the initial data loading effort required in the yards, will make digital structural data available to all design disciplines very early in detail design, and will greatly reduce the number of consistency-type errors in the contract design package.

## Benefits of Integrated Structural Design to Other Design Disciplines

The capability to obtain graphical displays, 'sketches and drawings of structural configurations would be available to designers in all disciplines. These designers would call for structural background graphics in whatever useful views they require, upon which they would variously carry out their tasks of equipment arrangement, piping and wireway routing, locating vent trunks and ducts, etc.

The integrated data base would contain equipment locations and details of piping connections on equipment, thereby providing precise end position and details for piping design.

A consistent record of structural penetrations would be maintained by the data base, correlating each penetration with the pipe, cable or vent duct involved, establishing the precise location and representing the details of the penetration.

The greatest benefit to be realized by integrating structural design with other disciplines will be regarding the control of physical interferences. Composite drawings and displays would acquire data from all disciplines to combine components from all relevant systems into one picture. As with the structural graphics capability, any views and various levels of detail may be prescribed. Several colors may be used to distinguish among systems. The composite capability would be cheap, easy, and would provide data highly consistent with the various system designs. Ancillary capability would include interactive resolution of interferences by allowing on-the-spot recommendations for modifications to remove conflicts, and analysis modules which would automatically detect interferences.

## New Benefits to Production

When the design/engineering functions begin using CAD, new benefits will accrue in the production process itself and there will be a marked improvement in economy of transition from design to production. The parts programming effort will be greatly reduced since a comprehensive digital description of the structural geometry will already exist.

In most shipyards using N/C methods the production is responsible for interpreting structural drawings, for loading the structural geometry onto the data base, and for updating the N/C data base in accordance with successive waves of drawing revisions. Much effort is currently expended in identifying these design mods and in the requisite data update. The production department in the future will be relieved of this responsibility, since an up-to-date, approved data base will be availble to them as a natural product of the integrated design process.

Having captured basic structural design in digital forms, these data become a "valuable resource in production planning. The structural pieces can be easily organized to form the assembly tree structure, thereby establishing the assembly units and assembly sequences. Assembly units would be complete with all small parts accounted for, and assembly weights would be computed automatically. Most N/C systems now provide N/C statistics, (burn path length and time, punching time, percentage scrap, etc.) as spin-off information for use in production planning. Similarly, a structural design data base would classify weld joints as to standard types and would quantify amounts of each joint type required during each assembly step.

Structural design data will also be massaged and outputted variously as specialized parts lists, special-purpose fabrication sketches, and isometric assembly sketches. Whereas these fabrication tailored shop instructions are expensive to produce manually, the computer can generate them very cheaply once the basic data are available.

Programs can assist in assembly lifting calculations by computing weight, center of gravity and forces, by showing the engineer the lifting sequence in interactive graphic animation, and by preparing sketches of the lifts in various possitions.

## Benefits Due to Coordination of Computer Methods Across the Industry

We have already discussed the escalating costs of developing and maintaining shipbuuilding computer software and have noted that this trend is driving us toward-cooperative effort in such software. More and more, users' clubs of various N/C systems are working together to implement standard "norms," specialized input procedures, etc. Whereas in the early years of N/C systems it was quite common for individual shipyards to customize versions of the software for their own use, we can see in the SPADES and AUTOKON Users' Groups a higher level of cooperative effort. In short, a higher level of standardization is being tolerated to attain lower costs, but this standardization gives occasion for other benefits also.

Perhaps because of the tight control on SPADES software andthe consequent standardized usage among the SPADES community, SPADES shipyards have been able to subcontract among each other portions of designs, thus easing the scheduling bind and leveling their manpower curves. While this type of flexibility has always existed in manual design, it must not be taken for granted with CAD processes because yards or design offices must use compatible systems in order for such subcontracting to be effective. Standardization of computer methods across the industry will allow management to retain the subcontracting option.

More than any other ship buyer, the Navy suffers from lead-yard/ follow-yard shipbuilding problems. The independent use of incompatible design software by different systems compounds the problem; cases have occurred where both lead and follow yards utilized CAD systems, but where the lead yard was required to repeat the design manually because the data from its CAD systems were unintelligible to the follow yard’s system. Translated into a national emergency situation, this peacetime cost problem becomes a severe constraint on the nation’s ability to rapidly produce naval and merchant fleets. As with subcontracting, a CAD system more integrated on the industry level will reduce the peacetime acquisition costs and the wartime defense constriction.

Finally, Industry-CAD integration would produce classes of ships -- Navy and commercial -- which are more nearly identical than most classes to date. This conformity has a significant impact on reducing life cycle costs attendant to logistics, spare parts, training, repair, and conversion.

## NECESSARY STEP TO CAD PAYOFF

Development of mature, effective shipbuilding CAD systems to produce the aforementioned benefits is no straightforward, task. Figure 8 records a number of the major problems we are encountering as we move toward more highly integrated systems. These problems are discussed in reference 11. It is not the purpose of this paper to address all these issues or their solutions. We will look closely at the last problem noted for these reasons: (1) it has not generally been given recognition appropriate to its significance; (2) it must be addressed now or it will be too late; and (3) there is something we can do about it,

The problem to be considered is that throughout the shipbuilding industry we are developing shipbuilding software to address particular immediate tasks. This distributed development effort is largely un-coordinated and we may be sure that those "successful" programs and systems which emerge will soon need to integrate with other programs/ systems, and that because of our lack of foresight, such integration will be difficult at best.

The Navy’s CAD development over the last decade indicates that the most serious barrier stems from differences in the ways that individual programs/systems represent their data. Programs/systems considered for integration generally contain overlapping sets of data. Each program has been designed to handle data to suit its own needs and has built into it determinations respecting the logical definition of data entities, the structure of the data, the data formats, and the various software to perform data mangement functions. These types of determinations represent substantial software commitments and alteration of the software to revise

PROBLEMS TO BE ENCOUNTERED WITH MORE HIGHLY INTEGRATED SYSTEMS

- RAP IDLY DEVELOPING TECHNOLOGY
  - GRAPHICS
  - DATA BASE MANAGEMENT SYSTEMS
- Ž REVOLUTIONARY VS. EVOLUTIONARY INTEGRATION STRATEGY
- Ž IMPACT ON CURRENT PRACTICE
- Ž HIGH COST OF COMPUTER SOFTWARE
- Ž SELECTION FROM AVAILABLE COMPETITIVE SYSTEMS
- Ž CONCURRENT UNCOORDINATED DEVELOPMENT OF SOFTWARE. WHICH WE WILL SOON TRY TO INTEGRATE

FIGURE 8

these items is generally an expensive proposition. As we have seen, the trend is that when independent programs become productive, users recognize the inefficiencies of their manual interfaces and propose they be integrated. It is at this point that the data differences among the programs prohibit integration. If we are to turn the corner on the high cost of progressive integration, we must better coordinate the data aspects of our respective software developments.

## Attacking the Data Consistency Problem

Let's consider what we can and cannot do to alleviate the data consistency problem in progressive integration.

First, we must be willing to project our vision beyond the immediate development tasks -- those which have visible cost justification -- to future needs calling for more complete integration. In this projection we must concentrate on the probable future data interfaces among system modules, identifying groups of design data which will be needed by two or more modules.

It would be very good if we were to be able to establish and enforce data consistency at the highest level, by agreeing to standard data management software and standard physical file structure. Although these measures can and should be used where possible at lower levels of integration (e.g., where programs are merged into subsystems within a company), it would be optimistic to think they could be applied now to industry-level system integration. Difficulties stem from the diverse requirements of applications, from the limited generality of today's data management technology in efficiently serving diverse requirements, and from the difficulty of accurately predicting long-range data management needs or state-of-the-art capabilities.

Accepting the impracticality of invoking those high level standards, let us proceed with the next best thing: to establish consistent logical definition of design data to serve immediate and long-term applications. Figure 9 summarizes those characteristics of data comprising its logical definition, as opposed to the physical definition of data. The segregation of logical and physical data definition is widely recognized as a critical factor in effective future systems. Interpreted to our situation, this segregation tells us that we users must get our logical definitions straight and that future data management systems must be responsible to provide efficient physical data structure without our applications programs being concerned with record length, blocking factors, string versus tree structures, etc.

The time for industry action in coordinating logical data definitions is now! Figure 10 lists seven different development, projects in the REAPS/

| LOGICAL DATA DEFINITION | PHYSICAL DATA DEFINITION |
|---|---|
| REFLECTS THE WAY THE APPLICATION 1 PROGRAMMER OR USER THINKS OF THE DATA. | REFLECTS THE CONSIDERATIONS OF THE COMPUTER SYSTEMS PROGRAMMER. |
| REPRESENT REAL WORLD ITEMS. OR APPLICATION PROGRAM MODEL OF THE REAL WORLD IN TERMS (IF ENTITES, ATTRIBUTES, AND LOGICAL RELATIONSHIPS AMONG ENTITES. | CONSIDERS WHERE ON STORAGE DEVICES A SET OF INFORMATION IS LOCATED, CONTENDS WITH RECORD LENGTHS, BLOCKING FACTORS, TYPES OF STORAGE DEVICES, TYPES OF PHYSICAL RELATIONSHIPS (STRING, LIST, ARRAY ORGANIZATION). |
| GOAL: TO PROVIDE APPLICATION PROGRAMMERS A NATURAL VIEW OF THEIR DATA, MAKING PROGRAMS EASIER TO DEVELOP AND MAINTAIN. | GOAL: TO ATTAIN EFFICIENT OPERATION ON WHATEVER DEVICES ARE USED. |

SEGREGATION OF LOGICAL AND PHYSICAL DATA DEFINITIONS INSULATES APPLICATION PROGRAMS FROM CHANGES IN-DATA STORAGE DEVICES AND FROM CHANGES IN PHYSICAL DATA MANAGEMENT METHODS.

FIGURE 9

THESE CURRENT DEVELOPMENTS HEAVILY INVOLVE SHIP STRUCTURAL DATA:

REAPS PARTS DEFINITION PROJECT

REAPS COST ESTIMATING PROJECT

NAVY'S CASDAC LEVEL III HULL SUBSYSTEM

NAVY'S CASDAC LEVEL IV HULL SYSTEM (HULDAC)

CONSOLIDATION OF AUTOKON76 WITH THE U. S. STANDARD AUTOKON 71 AND WITH THE NEWPORT NEWS, VERSION OF AUTOKON

CONSOLIDATED AUTOKON/SPADES FEASIBILITY STUDY

REAPS PROPOSED STRUCTURAL DATA BASE DEFINITION PROJECT

THE FUTURE IS NOW!

FAILURE TO COORDINATE LOGICAL DATA DEFINITIONS OF THE ABOVE DEVELOPMENTS WILL GUARANTEE MAJOR OBSTACLES TO NECESSARY FUTURE DATA INTERFACES IN THE U. S. SHIPBUILDING INDUSTRY.

FIGURE 10

Navy community alone, in which digital structural design data play a major role. Failure to coordinate the logigal definition of structural data in these projects will guarantee the existence of major obstacles to necessary future interfaces in the U. S. shipbuilding industry.

Several pioneering efforts have been underway this last year to contend with logical structural data definition. In our work with the Hull Detail Design and Construction (HULDAC) System, covering the hull discipline for CASDAC Level IV/V, we have been investigating methods of recording logical data definition for ship structure. Figure 11 is an example of part of a typical logical definition. We are coordinating our work on the hull data base evolving from that of the Naval Ship Engineering Center's CASDAC Level III Hull Subsystem, and we have been following closely the ongoing REAPS projects and have been including in the HULDAC study structural data requirements indicated by those projects.

In particular, the HULDAC work has been closely keyed to the Structural Data Base Definition effort initiated by Dick Moore of Newport News Shipbuilding Company and Doug Martin of IITRI and proposed to be adopted as a REAPS research and development project. At the February 1978 REAPS Technical Representatives Meeting, IITR1 presented a Project Proposal Abstract and a Working Paper describing this proposed project and requesting technical inputs from the REAPS member yards. Initial response to this effort was not enthusiastic, apparently because the relevance of this project to the future anticipated benefits of computer usage in shipbuilding was not clearly set forth. It is the purpose of this paper to illuminate and publicize the rationale for this project.

## Recommended Action to Coordinate Ship Data Definition

Figure 12 enumerates several actions which should be taken to better coordinate the logical definition of ship data. These actions should concentrate first on structural data due to the intense development activity in this discipline, but should eventually be extended to include piping and other design disciplines.

A key component of this effort should be the execution of Structural Data Definition as a REAPS research and development project, with active support in defining data needs from knowledgeable structural engineers within each yard. Close liaison must be maintained between this project and the structural data being defined by the Navy to serve HULDAC and CASDAC Level III.

Once an acceptable Structural Data Definition has been created, a challenging organizational/control problem will be to establish a continuing mechanism whereby developers and users of shipbuilding systems will be influenced to observe the standards.

## LOGICAL DATA STRUCTURE

PLATE
- PARENT-SURFACE
- MATERIAL-CODE
- THICKNESS
- EDGES (RG)
  - CONTOUR-NAME
  - EXCESS-STOCK
  - BUTT-JOINT-DETAILS (RG)
    - ADJOINING-PLATE
    - STD-JOINT-TYPE
  - MOLDED-EDGE-CONTOUR
  - AUGMENTED-EDGE-CONTOUR

## LOGICAL DATA I) DEFINITIONS

**PARENT-SURFACE:** IDENTIFIES THE DECK, BULKHEAD, SHELL SURFACE, ETC., WHIHIcH CONTAINS THE PLATE

**EDGES (RG):** REPEATING GROUP OF PLATE EDGES, EACH EDGE BEING DEFINED BY A BUTT, SEAM, OR INTERSECTION CONTOUR WITH ANOTHER STRUCTURAL SURFACE (E.G., MAIN DECK AT EDGE).

FIGURE 11

## RECOMMENDED COORDINATION IN SHIP DATA DEFINITION

- CARRY OUT STRUCTURAL DATA-DEFINITION PROJECT AS FORMAL REAPS PROJECT.
  - YARD PARTICIPATION TO REVIEW DEFINITIONS AND USAGE.
  - COVER DATA IN USE AND DATA FOR SOFTWARE BEING DEVELOPED.
  - CLOSE COORDINATION WITH NAVY DATA DEFINITION.
- ESTABLISH MECHANISM FOR CONTINUING DATA COORDINATION.
  - CASD DEVELOPERS MUST ADHERE TO STANDARD DATA DEFINITIONS.
  - CASD DEVELOPERS MUST SUBMIT NEW DATA FOR INCLUSION.
- EXPAND DATA DEFINITION TO INCLUDE PIPING, HVAC, ETC.

FIGURE 12

## SUMMARY

It has been shown that two of the most dominant trends in the continuing evolution of shipbuilding software systems are the increasing cost of developing and maintaining this software and the recursive cycles of higher integration being sought, especially now in the *detail* design/engineering functions. We must recognize these trends and lay strategy to accommodate them through more cooperative effort and by extending our vision in system planning beyond the immediate development tasks to encompass the imminent higher levels of integration beyond.

The effects of-the trend toward higher integration are expected to produce large benefits to the design/engineering functions of all disciplines, to produce additional benefits to the production function, and to upgrade the effectiveness of the U. S. shipbuilding industry as a whole.

One very important necessary step toward long-term 'integration is to gain control of the diverse logical data definitions,bei:ng built into concurrently developed programs and systems. A number of current developments involve overlapping structural design data and the involved parties -- REAPS and the Navy in particular ' should actively promote coordination of this common data.

The Structural Data Definition project should be recognized as a vital undertaking, to be pursued with vigor and with high level support from shipyard management.

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